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Scratching the surface: Learning styles, practice and the acquisition of high-level representational drawing ability

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Abstract

Accurate representational drawing is a complex skill which underpins performance in many branches of the visual arts. Research suggests that expertise typically is acquired as a result of deliberate practice and a flexible approach to learning strategies. The current study investigated how, in art students, differences in the acquisition of observational drawing skill could be characterised using domain-general expertise accounts. A cohort of undergraduate and postgraduate art students (n=682) completed questionnaires about self-perceived artistic abilities, personality and approaches to learning. A subset completed tasks of actual drawing ability (n=301), the Rey-Osterrieth Complex Figure (ROCF) test and a performance IQ test. Actual drawing ability related to time spent drawing and drawing techniques, with additional independent predictive effects of both the copying and delayed ROCF test. Effects of personality were mainly mediated via learning styles, with surface learners spending more time drawing, learning fewer techniques and acquiring a lower level of actual skill. Deep learners learned more drawing techniques, and strategic (achieving) learners acquired a higher level of drawing skill overall. The resulting model of drawing ability development has the potential to be generalised over a range of creative and non-creative domains.

Introduction

The production of representational art is a complex human skill. The vast majority of children engage in drawing behaviours to some extent throughout their childhood, however at some stage most abandon drawing, becoming increasingly entrenched in a world that seemingly favours linguistic competency over visual expression (Arnheim, 1969). Despite a wealth of evidence on the impact of individual differences on expertise development in domains such as chess, music and sport, there is little empirical investigation into the development of artistic skill. The current study aimed to determine the correlates of high-level representational drawing, a key foundation of many branches of the visual arts.

Personality has been shown to explain some of the variance in expertise development. These differences have been explored in relation to a range of domains, and therefore are also likely to impact upon development of expertise in the visual arts. Openness to experience and the closely related trait of sensation seeking (Aluja, García, & García, 2003) predict skill in sport (Anshel, 2012), chess (Bilalić, McLeod, & Gobet, 2007) and music (Corrigall, Schellenberg, & Misura, 2013; Vuust et al., 2010), suggesting that the ability to flexibly approach strategies for expertise development is an indicator of later success. In addition, individuals with high intrinsic motivation are more likely to develop expertise in sport (Singer & Orbach, 1999) and chess (Grabner, Stern, & Neubauer, 2007), suggesting that conscientiousness plays a role in the development of expertise.

Individual differences in personality also affect approaches to learning, which in turn could impact on the degree to which those pursuing expertise in a domain will achieve success. Approaches to learning can be measured using the Study Process Questionnaire (SPQ; Biggs, 1987a, 1987b). The SPQ has a three dimensional structure composed of surface, deep and achieving (strategic) approaches to learning and attainment. Surface approaches are motivated by a fear of failure which results in strategies which are dominated by rote learning of facts, strategies which often are counter-productive (Tooth, Tonge, & McManus, 1989). In contrast a deep approach to learning is driven by interest in the subject matter itself, and results in strategies driven by the understanding of principles and ideas, resulting in the integration of ideas to one another and to a wider domain. Finally, an achieving style (also known as a strategic style) is motivated primarily by a desire for success, with topics being studied primarily in terms of their likelihood of being useful in competition, so that understanding varies mainly according to its relationship to the goal of achieving high grades (Biggs, 1987a; Fox, McManus, & Winder, 2001). Learning styles have long-term predictive validity for assessing outcomes in a range of disciplines, and have particularly been looked at by one of us in medical students and doctors, where they go on also to predict behaviour in the workplace (McManus, Keeling, & Paice, 2004; McManus, Richards, Winder, & Sproston, 1998). Specific approaches to learning have been found to be underpinned by differences in personality in the past. Deep approaches to learning are associated with openness to experiences and achieving approaches

to conscientiousness (Chamorro-Premuzic & Furnham, 2008), both of which have been associated with expertise development and were the subject of focus in the current study.

The primary aim of the current research was to explore whether individual differences in personality and approaches to studying predict both actual and self-perceived drawing ability. A secondary question was to what extent factors previously found to be associated with representational drawing proficiency, such as visual memory and visual imagery (McManus et al., 2010), interact with individual differences in personality and approaches to studying. The role of academic attainment and performance IQ in representational drawing skill was also explored, in order to account for potential interactions between general cognitive functioning, study approaches, and representational skill.

On the basis of previous research it was hypothesised that art students who showed deep and achieving motivations for study rather than surface approaches would be more likely to engage in meaningful and productive practice and thus develop a higher level of observational drawing expertise. A deep approach to learning was hypothesised to be underpinned by openness to experience, whilst an achieving approach was predicted to be underpinned by individual differences in conscientiousness based on previous research (Chamorro-Premuzic & Furnham, 2008). It was also hypothesised that there would be positive relationships between visual imagery, visual memory performance and observational drawing ability, but that these connections would form a separate strand of correlation, independent from associations with personality/study approaches.

Method

Participants.

The data in the present analysis were collected in several different studies in the years 2007, 2010, 2011 and 2012. Practical constraints inevitably meant that not all measures could be used on all occasions. Participants were foundation year art and design students from Swansea Metropolitan University (SMU, n=453) and first year post-graduate art and design students from the Royal College of Art (RCA, n=263). The total sample consisted of 682 participants.

Apparatus and Procedure.

Questionnaire

Participants completed a questionnaire consisting of a single folded sheet of A3 paper. The questionnaire included questions on:

1. *Self-perceived artistic and design ability.* Participants were asked about how they perceived their ability at a wide range of artistic, design and other skills in relation to other individuals studying art and design. Responses were indicated on a 5-point Likert-type scale ranging from 'much above average' to 'much below average'. As in a previous study (McManus et al., 2010) a single averaged measure was constructed from the answers to five items, which is called **Self-rated Drawing Ability**.
1. *Drawing and painting experience.* Amount of time spent drawing and painting currently and over the current and previous years. The 11-points of the scale ('most days for 4+ hours/2-4 hours/1-2 hours/>1 hour', 'most weeks for 2-3 hours/1 hour', 'most months for 2-3 hours/1 hour', 'over the year 3-6 hours/1-2 hours', and, 'never') were scored from, eleven to zero. For the present study we considered only time spent drawing, averaging the points to produce a measure of **Drawing Time**.
2. *Observational Drawing Methods.* Participants were presented with a list of techniques used in the teaching of observational drawing (*using a plumb line, using an outstretched finger, focusing on negative space, squinting/blurring the eyes, framing a view with the hand, triangulation, focusing on pattern/textured, quick drawing, knowledge of anatomy/mechanics, closing one eye, sketching out the pivotal geometry of a scene*). Participants were asked to indicate how often they adopted each technique in their own practice, placing their answers on a 4-point scale from 'use it frequently' to 'never heard of it'. The overall average resulted in a measure called **Drawing Techniques**.
3. *Big five personality measures.* Later participants were provided with the 15 item list of questions from the Household Panel Survey based on the Big Five Inventory (John, Naumann, & Soto,

2008; John, Donahue, & Kentle, 1991) while earlier participants responded to similar items based on the NEO-FFI (Furnham, McManus, & Scott, 2003). Individual responses were on a 5-point scale. In order to equate the two methods of measuring the Big Five, results from each of the two measures were converted to Z scores and then merged. Scores were calculated for the standard Big Five dimensions, resulting in measures of **Neuroticism (N)**, **Extraversion (E)**, **Openness to Experience (O)**, **Agreeableness (A)** and **Conscientiousness (C)**.

1. *Study Habits/Learning styles.* The Study Process Questionnaire assesses the self-rated study habits and learning styles on three separate scales (SPQ Surface Learning, Deep Learning and Achieving (Strategic) Learning). A shortened version of the question was presented (Fox et al., 2001) which had 18 items, each on a 4-point scale ranging from '*strongly agree*' to '*strongly disagree*'. The three measures were called **SPQ Surface**, **SPQ Achieving** and **SPQ Deep**.
2. *Vividness of Visual Imagery* (Marks, 1973). Participants were asked to visualise a verbally described visual scene and then rate the vividness of the resulting mental image on a 5-point scale ranging from '*No image at all, I'm just thinking about the object*' to '*Perfectly clear and vivid as normal vision*'. This was completed for two separate scenes and for several aspects of the scenes. A single overall measure was used for the analyses by summing responses for each aspect of each scene and was labelled as **VVI**.
2. *Educational background.* GCSEs, AS-levels and A-levels attained for all subjects including art and design. In the UK, GCSEs are taken at age 16, often in eight or more subjects, in a range of disciplines. AS-levels are taken in a smaller number of subjects at age 17 and A-levels at age 18. For present purposes a single measure was constructed of the average grade attained at all GCSE subjects, and is called **GCSEs**.
3. *Demographics.* Gender, date of birth, nationality, and parental practice and sympathy toward the arts were assessed. The only measure analysed here is sex, scored as 1=Male and 2=Female, so that the variable can more conveniently be labelled as **Female**, positive correlations indicating that females score more highly on a scale.

Drawing and other timed tasks.

A proportion of the participants (n=302) took part in a series of timed drawing and other assessments. The drawing and perceptual tasks were either completed in the same A4 size paper booklet as the questionnaire or participants were provided with sketch books. Drawing materials included HB pencils, erasers and sharpeners. Visual stimuli (Figure 1) were presented either via a Microsoft Office PowerPoint presentation projected onto a 4m x3m screen or in some cases were provided in the test booklet. Participants were tested in groups of up to 15.

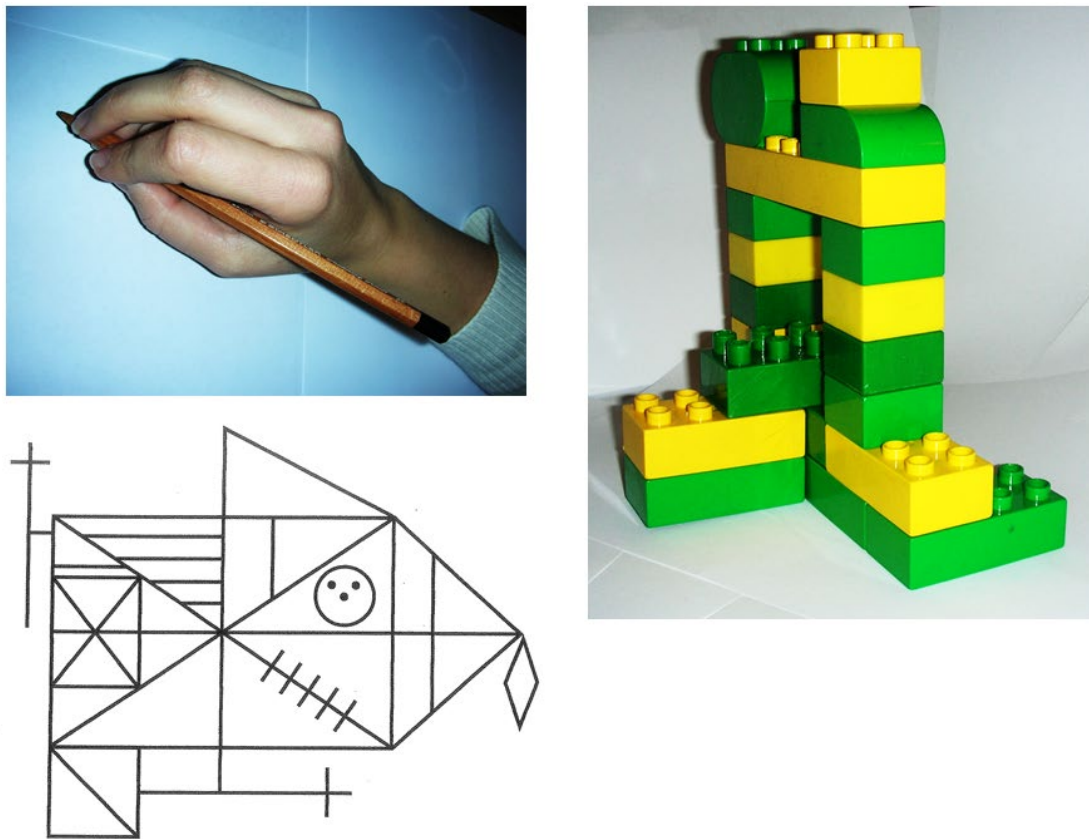


Figure 1. Photographs used in the drawing task (above) and Rey Osterrieth Complex Figure (below)

The tasks included:

1. *Representational drawing tasks.* In the two separate tasks, each of which lasted five minutes, participants were shown a coloured photograph of a hand holding a pencil and a construction made of blocks (see Figure 1). Participants were asked to make an accurate drawing of each of the photographic stimuli. The quality of the drawings was assessed in a separate study, using techniques described previously (McManus et al., 2010). Black and white digitised images of the drawings and the original image were printed out onto sketching quality paper, reduced from A4 to A5 size. The images were then rated by a convenience sample of ten non-expert judges consisting of postgraduate and undergraduate students at UCL. Each judge was required to rate the drawings from best to worst by sorting them on a large table into seven categories. Judges were informed that quality of drawing was to be determined solely on the basis of accuracy, and not on aesthetic appeal. Exemplars of the quality of drawing accuracy in each category from a previous study were given to the judges in order to aid the rating process. The judges were not restricted in terms of how many drawings they put into one category. When the judges were satisfied with their distribution of drawings, each drawing was assigned the number of the category it was placed in (8 – best, 2 – worst). If a judge felt that a particular drawing was better than the best exemplar, that drawing received a score of 9, and if a drawing

was rated as worse than the worst exemplar, it received a score of 1, although these extremes of the scale were used rarely. Previous analyses (Chamberlain, McManus, Riley, Rankin, & Brunswick, 2013) have found that the reliability of the ratings (Cronbach's alpha) was about .92 for the hand drawing and .93 for the blocks drawing. The averaged rating for the hand and blocks drawings resulted in a single measure of overall **Actual Drawing Ability**.

2. *Rey Osterrieth Complex Figure* (Rey & Osterrieth, 1993) The Rey-Osterrieth Complex Figure (ROCF) is a complicated geometrical figure used in assessing visual perception and visual memory (Figure 1). It was tested in two conditions. *Copying Condition*. Participants were given four minutes to make a copy of the ROCF. They were not informed that they would have to remember the figure later. *Delayed Recall Condition*. Without prior warning, participants were asked to re-draw the ROCF from memory, approximately 30 minutes after they initially copied it, without looking back at the original ROCF or their copy. Scoring used the conventional method in which 18 separate features were assessed, each being scored as 0, 1 or 2. (Rey & Osterrieth, 1993). The two separate measures from the ROCF are called **ROCF Copy** and **ROCF Delay**.
3. *Shortened Form of Ravens Advanced Progressive Matrices*. In view of the general interest in the role of general cognitive ability in the acquisition of skill and attainment, the participants in one group received a shortened form of Ravens Advanced Progressive Matrices (RAPM). This form has been validated and normalised (Arthur, Tubre, Paul, & Sanchez-ku, 1999) and as such represents a valid predictor of non-verbal IQ (NVIQ). Participants were given one practice item from Set I of the RAPM. They were then given 12 items from Set II of the longer 36 item RAPM to complete in 15 minutes. All participants completed the task in the allotted time. The measure of non-verbal cognitive ability is here called **NVIQ**.

Statistical Analyses

Multiple Imputation and Missing Values

The data in the present analysis were collected in several different studies over a period of years. Practical constraints inevitably meant that not all measures could be used on all occasions. Some measures were found not to be correlated with drawing ability and were dropped, and other measures were introduced as our theoretical understanding of drawing increased. The result is what might be called a 'patchwork dataset', typical of many such datasets which are collected in real world analysis of complex problems, where knowledge and understanding develops as the studies progress. An additional problem was that although our 'gold standard' measure involved participants carrying out two representational drawings under controlled conditions, that could only take place for subsets of the participants, many others only completing questionnaire measures. The result is that few measures are present in all participants and there are extensive missing data. Fortunately given modern statistical methods, that need not be a problem, particularly using multiple imputation. Our data collection method can be seen as variants on the two separate approaches of Graham et al

(Graham, Taylor, Olchowski, & Cumsille, 2006) who describe what they call 'planned missing data designs', which have greater efficiency for assessing effects of multiple predictor variables. In their '3-Form design' all participants receive a core set of items, but then each of the three groups then receives separate subsets of the remaining predictor variables, thereby reducing the time spent by each participant on answering questionnaires. Our data, if less planned and less systematic than Graham et al's (2006) three groups, are essentially similar in structure, the different groups receiving separate but overlapping sets of items, with a core set of measures being used in almost all participants.

Both of Graham et al's (2006) approaches rely on using modern statistical methods for handling missing data, the data which are missing being imputed on the basis of all that is known about the means and covariances of the data which are present. Traditional approaches to missing data (see Graham et al (2006) for a review of this and other methods) have used methods such as listwise deletion, which would leave us with almost no data. Simple methods such as mean substitution can be effective but result in biases as the imputed data have a zero variance. Similarly the EM (Expectation-Maximisation) algorithm can also result in biased imputed data, since all must, of necessity be on the various regression lines. The most satisfactory method is undoubtedly multiple imputation in which imputation takes place repeatedly, with the random variance of imputed data points around the regression lines being included in the model. The result is a set of, say, 100 imputed data sets, all of which contain the same set of actual measurements, but randomly different sets of imputed values. Programs such as IBM SPSS can then carry out regression analyses on each separate imputed dataset, and the estimates from those individual analyses then are combined to obtain overall estimates after imputation. That is the method we have used here. Our analyses have a number of different predictor and outcome variables, and therefore path analysis is a natural way of handling the measures. Our models are simple in that we have only used measured variables, without any latent variables, and we do not attempt to take measurement error into account. Such models can be fitted using conventional multiple regression programs (Kenny, 1979), and hence when combined with multiple imputation can still be fitted using conventional statistical programs such as IBM SPSS. Thus in the current study missing values were handled using multiple imputation (Schafer, 1999) which was carried out using the MVA program in IBM SPSS v22.0, generating 100 imputed (MI) datasets.

Path analysis was conducted in a conventional way, and since all of the variables were measured variables rather than latent, estimation of path coefficients used multiple regression. The causal ordering was theoretically based, and is described in more detail below. In the path diagrams, variables are placed from left to right, variables to the left being able to cause those to the right. Where the causal ordering of variables could not adequately be resolved they are placed vertically above one another. We followed the approach of Kenny (1979) in which regression was firstly used to fit a saturated model in which each measure was the dependent variable and all variables to the left

were predictors, with non-significant predictors being dropped sequentially from the model. An unconventional feature of the path modelling was that the regression was carried out on the set of imputed datasets, using the combined significance levels across the imputed sets provided by SPSS. The measures are mostly on different, arbitrary and non-comparable scales, and therefore all measures were converted to z-scores before imputation was carried out in order that combined estimates were on a standard scale (i.e. they are beta coefficients).

Our analysis was in large part exploratory, no previous studies having examined the role of the majority of these measures, and therefore the significance level was set at $p < .05$, while acknowledging that this may be somewhat too liberal. Significance levels of paths are indicated in the diagrams, so that the effects of a more stringent criterion can be observed. In addition the correlation matrix is presented as an appendix, allowing the interested reader to recalculate the models under different assumptions.

Results

Analysis of the results will take place in two stages, firstly considering the separate measures and their simple correlations with the outcome measures, both in the raw data sets and in the 100 MI datasets (for all simple correlations between raw and MI datasets see Appendix) and then through two path analyses of the MI dataset. Table 1 summarises the descriptive statistics for the raw data, and the descriptive statistics for the multiply imputed datasets.

Table 1. Descriptive statistics and regression table with drawing rating dependent variable for questionnaire measures included in the later path models (see Figures 2 & 3)

Variables	Original Dataset		Multiply Imputed Datasets	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Big Five (N=199)				
Neuroticism	0 ⁺	1 ⁺	.0036	1.0044
Extraversion	0 ⁺	1 ⁺	.0017	1.0067
Openness to experience	0 ⁺	1 ⁺	-.0025	1.0017
Conscientiousness	0 ⁺	1 ⁺	-.0005	.9968
Agreeableness	0 ⁺	1 ⁺	-.0019	1.0004
Visual Imagery (N=110)				
VVI	3.54	.73	3.45	.81
Study Process (N=133)				
Deep	17.61	3.42	17.51	3.32
Achieving	16.49	2.98	16.21	3.37
Surface	12.94	3.48	12.95	3.62
Practice (N=200)				
Drawing time	12.20	5.22	12.38	5.41
Drawing techniques	2.30	.54	2.33	.58
Visual Memory (N=175)				

ROCF Copy	31.88	4.03	31.17	3.59
ROCF Delay	21.62	5.96	21.45	5.92
Artistic Skill (N=575)				
Actual drawing ability	4.33	1.05	4.41	1.07
Self-rated drawing ability	3.17	.65	3.17	.65

Notes: * $p < 0.05$; ** $p < .01$; + measures set as z-scores with mean 0 and SD 1.

Actual drawing ability

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Hand drawing ratings significantly positively correlated with block drawing ratings, $r(293) = .61$, $p < .001$, and therefore a composite measure of actual drawing ability was produced by averaging drawing ratings for the hand and blocks for each participant.

Self-rated drawing ability

Self-rated drawing ability correlated significantly with actual drawing ability ($r = .40$, $p < .001$).

Drawing techniques.

Responses to the questions on different drawing techniques were explored using Principal Components Analyses, and there was strong evidence for a single underlying factor, meaning that if an individual used one technique then they were more likely to use others (Eigenvalue=4.07, 36% of variance explained). There was however some suggestion that use of a plumb line was an exception. Drawing technique usage correlated with externally rated drawing ability, $r(142) = .28$, $p < .01$. The use of the various techniques was summarised as the sum of responses to each of the different techniques, to give an overall measure of **Drawing techniques**.

Drawing Time.

The amount of time spent drawing in the current and last year was positively correlated with actual drawing ability ($r(209) = .14$, $p < .05$).

Personality.

A multiple regression was conducted with objective ratings of drawing ability as the dependent variable and the five personality factors: neuroticism (N), extraversion (E), openness to experience (O), agreeableness (A) and conscientiousness (C) as predictors. The regression model was not significant and none of the five personality variables predicted drawing ability.

Study Habits.

Three study habit styles (SPQ Deep, Achieving and Surface) were derived by summing the relevant responses to target questions pertaining to each of the three styles. In a regression in which

objectively rated drawing ability was the dependent variable surface strategies to learning were negatively predictive of drawing rating ($\beta = -.22$, $p < .05$). Differences in approach to studying only accounted for 7% of the variance in drawing scores.

Rey-Osterrieth Complex Figure.

Both the ROCF Copy ($\beta = .23$, $p < .01$) and ROCF Delay ($\beta = .23$, $p < .01$) conditions of the ROCF complex figure test independently predicted performance on the hand and block drawing tasks and together accounted for 16% of the variance in actual drawing ability.

Educational Attainment.

GCSE scores were computed for each participant, and these were correlated with externally rated drawing scores. Externally-rated drawing ratings correlated significantly with mean GCSE grade, $r(207) = .22$, $p < .01$. However when included in the path analysis GCSE scores no longer predicted actual drawing ability and were therefore excluded.

NVIQ.

NVIQ scores were computed for each participant and then correlated with externally rated drawing ability. NVIQ was not significantly correlated with actual drawing ability.

Vividness of Visual Imagination.

VVI was computed by summing the responses to each of the 8 items on the questionnaire. Vividness of visual imagery was uncorrelated with actual drawing ability.

Missing values and multiple imputation.

Data were available for 682 participants on 18 variables, all of whom had at least one variable present. Of the 12276 possible data values, 5699 were present, meaning that 46.4% of the data were present. The median number of data points per participant was 10 (mean=8.35).

Path Analyses.

Two separate path analyses will be carried out, starting with what we think of as the 'drawing backbone', the four central measures related to drawing ability, which assess the relation between practice time, drawing devices, actual drawing ability and self-rated drawing ability. Finally we construct a more complex path model which as well as including personality and other background variables, also includes performance on the Rey-Osterrieth Complex Figure task.

Path analysis of the 'drawing backbone'.

Figure 2 shows the hypothesised causal relations of the four primary measures concerned with drawing ability. Actual drawing ability is conceptually the central variable, and we presume that it in

part causes higher self-rated drawing ability (the converse causal relationship seeming unlikely). Actual drawing ability is likely to be caused by more practice (Drawing Time), drawing in most cases being practised over a period of years, and hence Drawing Time, which is the integral of drawing over the previous two years, is at the left of the diagram. The use of more Drawing Techniques seems likely to be caused by having spent more time drawing, and hence it is between Drawing Time and Actual Drawing Ability. Simple correlations between the four measures are shown in the appendix and all are positive and significant. The path model in figure 2 was fitted using the regression approach described earlier (Multiple Imputation and Missing Values). The main backbone is that Drawing Time causes the use of more Drawing Techniques, which causes better Actual Drawing Ability, which in turn determines higher Self-rated Drawing Ability.

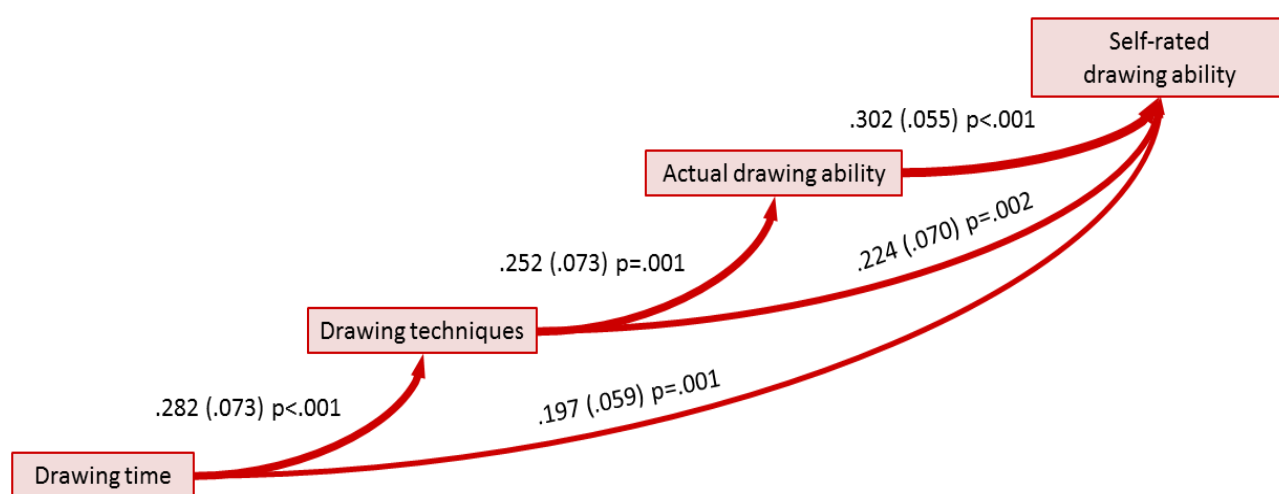


Figure 2: Path model for the four core measures of drawing with Beta coefficients and standard errors, resulting in the 'drawing backbone'. See text for details of the fitting process.

In addition Drawing Time and the use of more Drawing Techniques each have additional effects on Self-rated Drawing Ability. Interestingly, the only effect of Drawing Time on Actual Drawing Time is mediated through the learning of more Drawing Techniques, suggesting that it is not time per se, but time used in effective ways which increases Actual Drawing Ability. This is more fully elucidated in the second path model.

Path analysis of the ROCF and effects of personality and other measures on drawing ability.

Structure of the model. A striking feature of our previous studies (McManus et al., 2010) has been that an important predictor of drawing ability has been performance at drawing the ROCF. We therefore included the two measures of the ROCF (Copy and Delay), as well as 12 other background variables (sex, Big Five, VVI, three Study Habits, NVIQ and GCSEs). The causal ordering of the background variables is complex, and in part follows that used previously (McManus et al., 2004),

where sex is assumed to be at the far left, not being caused by any other variables, and the Big Five personality measures are placed next, being stable through much of the life-span. Study habits are placed to the right of personality, previous studies showing that in part they are modifiable by learning experiences (Fox et al., 2001), and that they are likely to be caused in part by personality (McManus et al., 2004). NVIQ and GCSE attainment are placed to the right of study habits, although there is an argument that NVIQ could be placed together with the Big Five personality measures. Finally, it was not entirely clear where to place VVI, and, somewhat arbitrarily, it was placed between the Big Five and study habits. The ROCF is placed immediately before Actual Drawing Ability on the grounds that it is itself a drawing ability, but is for much simpler images, and hence ability at it is likely to cause Actual Drawing Ability, rather than vice-versa.

ATTITUDES TO LEARNING & ARTISTIC SKILL

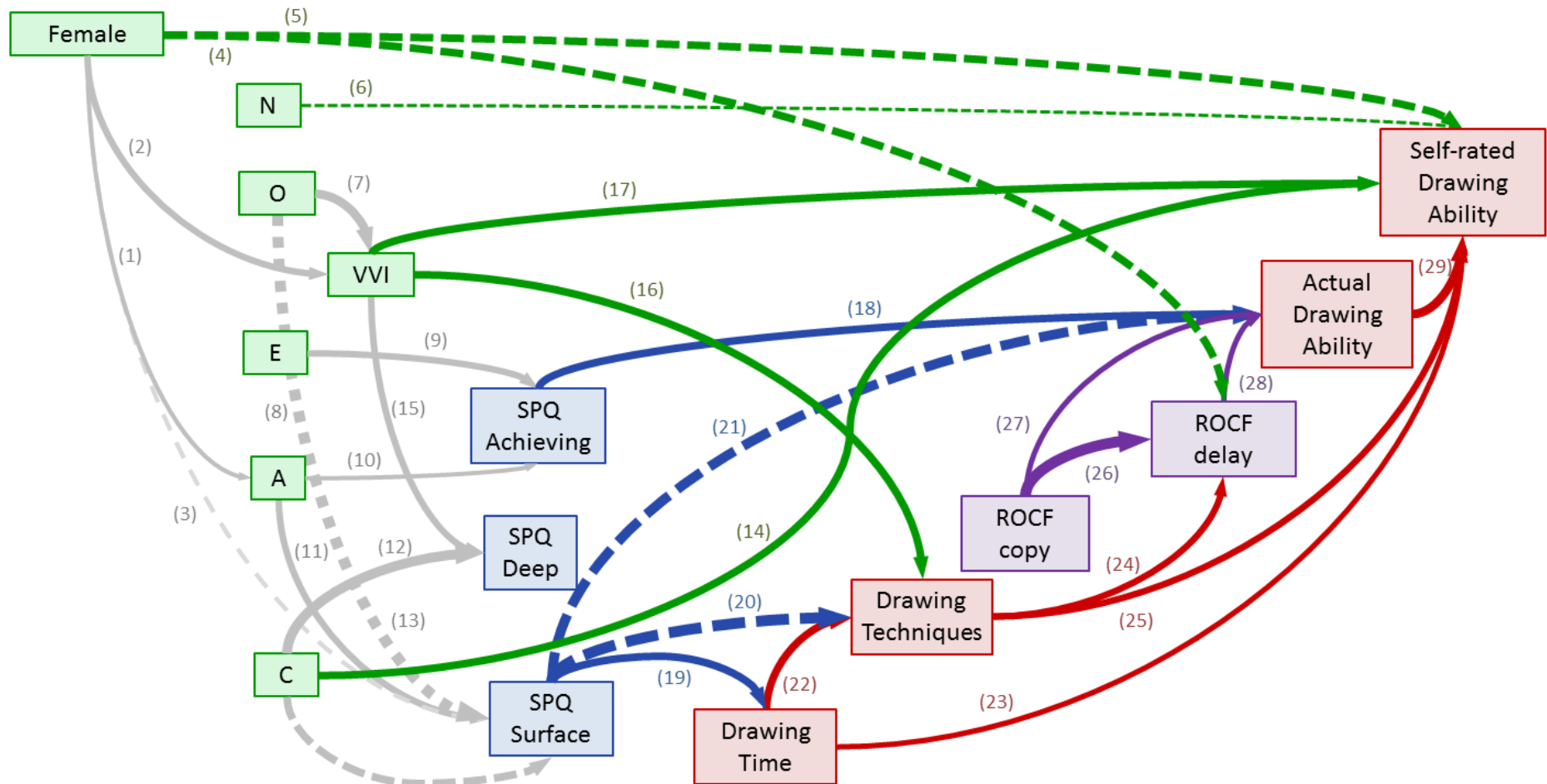


Figure 3: The full path model relating background variables to the four measures of drawing, and the two measures of the ROCF. Path widths are proportional to the size of the beta coefficients, and are colour-coded to allow easier navigation (see Results section). Paths with positive beta coefficients are drawn as solid lines and those with negative beta coefficients as dashed lines. Numbers alongside lines, where paths exit from their starting variable, and which are colour-coded in the same way as the lines, indicate the entry in table 2, where beta coefficients, their standard error, the t-statistics and the p values can be found.

ATTITUDES TO LEARNING & ARTISTIC SKILL

Table 2. Estimates of significant beta coefficients in the path model. Labels correspond to the paths in figure 3.

Label	Path from:	Path to:	Beta (SE)	t(676 to 680 df)
(1)	Female	Agreeableness	.153 (.046)	t=3.342, p=.001
(2)	Female	VVI	.174 (.088)	t= 1.981, p=.050
(3)	Female	SPQ surface	-.171 (.067)	t= -2.530, p=.012
(4)	Female	ROCF delay	-.150 (.067)	t= -2.223, p=.028
(5)	Female	Self-rated Drawing Ability	-.248 (.048)	t= -.5.14, p<.001
(6)	Neuroticism	Self-rated Drawing Ability	-.108 (.044)	t= -2.466, p=.014
(7)	Openness	VVI	.313 (.086)	t= 3.625, p<.001
(8)	Openness	SPQ surface	-.376 (.066)	t= -5.713, p<.0001
(9)	Extraversion	SPQ achieving	.200 (.078)	t= 2.552, p=.012
(10)	Agreeableness	SPQ achieving	.157 (.080)	t= 1.973, p=.050)
(11)	Agreeableness	SPQ surface	.257 (.075)	t= 3.409, p=.001
(12)	Conscientiousness	SPQ deep	.259 (.070)	t= 3.727, p<.001
(13)	Conscientiousness	SPQ surface	-1.68 (.074)	t= -2.281, p=.024
(14)	Conscientiousness	Self-rated Drawing Ability	.091 (.045)	t= 2.012, p=.045
(15)	VVI	SPQ Deep	.280 (.078)	t= 3.581, p<.001
(16)	VVI	Drawing Techniques	.257 (.087)	t= 2.954, p=.004
(17)	VVI	Self-rated Drawing Ability	.207 (.076)	t= 2.743, p=.007
(18)	SPQ achieving	Actual Drawing Ability	.234 (.101)	t= 2.312, p=.022
(19)	SPQ surface	Drawing Time	.236 (.078)	t= 3.023, p=.003
(20)	SPQ surface	Drawing Techniques	-.323 (.065)	t= -4.980, p<.001
(21)	SPQ surface	Actual Drawing Ability	-.309 (.090)	t= -3.442, p=.001
(22)	Drawing Time	Drawing Techniques	.385 (.069)	t= 5.551, p<.001
(23)	Drawing Time	Self-rated Drawing Ability	.240 (.058)	t= 4.146, p<.001
(24)	Drawing Techniques	ROCF delay	.251 (.102)	t= 2.458, p=.015
(25)	Drawing Techniques	Self-rated Drawing Ability	.173 (.073)	t= 2.354, p=.020
(26)	ROCF copy	ROCF delay	.364 (.073)	t= 4.978, p<.001
(27)	ROCF copy	Actual Drawing Ability	.220 (.074)	t= 2.971, p=.003
(28)	ROCF delay	Actual Drawing Ability	.241 (.085)	t= 2.833, p=.005
(29)	Actual Drawing Ability	Self-rated Drawing Ability	.299 (.053)	t= 5.621, p<.001

Links between background variables. All background variables were tested for inclusion in the complete path model. NVIQ and GCSEs showed no links onto any of the drawing or other outcome measures (although sex, O and A all predicted GCSE grades) and therefore for simplicity they are not included in the path diagram. All other measures showed direct or indirect effects on the drawing-related measures and are shown in figure 3. For clarity, links between background variables (on the left-hand side of the diagram) are shown in grey (solid for positive paths and dashed for negative paths), and they are mostly not of substantive interest for present purposes except for assessing indirect effects on drawing.

The drawing backbone. The drawing backbone model previously fitted in figure, 2 is shown with red paths in the right-hand side of the diagram (and all paths are positive), as also are paths involving ROCF copy and delay which are shown in purple. An important difference from figure 2 is that there is no direct link from Drawing Techniques to Actual Drawing Ability, and it can be seen that instead this is now mediated by ROCF delay. ROCF copy also has both a direct effect on Actual Drawing Ability, which is independent of ROCF delay, but is not influenced by any other measures.

Background variables and drawing variables. The paths from the background variables to the various drawing-related measures are shown in blue and green, blue paths pertaining to the study process measures and green pertaining to the demographic and personality measures. The three SPQ learning styles each show a different relationship to drawing. SPQ surface learning relates positively to Drawing Time, SPQ deep learning relates to Drawing Techniques, and SPQ achieving (strategic) style relates positively to Actual Drawing Ability. In addition SPQ surface learning relates negatively to Drawing techniques and Actual Drawing Ability. None of the other background variables relate to Drawing Time, Drawing Techniques or Actual Drawing Ability, all effects being mediated through learning style. In contrast, several background variables have effects upon Self-rated Drawing Ability, which is rated higher, after taking Actual Drawing Ability into account, in males, and in those with lower neuroticism, lower openness to experience, and higher vividness of visual imagination. A final point of some theoretical interest is that neither ROCF copy nor ROCF delay relate to any of the background variables, with a single exception, although both predict Actual Drawing Ability. ROCF delay does relate to Sex, males scoring somewhat higher than females, after taking ROCF copy into account.

Overall fit of the model. It would be desirable to have an estimate of the overall fit of the model to the data. However the substantial amounts of missing data make that difficult. An attempt was made to use full-information maximum likelihood modelling in LISREL 9.1 to fit a model similar to that in figure 3, but none of the paths reached significance. That clearly is not compatible with the strong associations found in figure 3 and it implies some problem within LISREL, and we have not explored it further.

Discussion

The aim of the current study was to characterise the development of representational drawing in training artists through the exploration of a constellation of mediating factors, including: personality, approaches to studying, intellectual ability, visual memory, visual imagery, technique use and drawing practice.

A central theme from the resulting data is what we term the 'drawing backbone'. This is a model in which actual drawing ability is primarily caused by having learned more drawing techniques, and having more drawing techniques is largely caused by more time spent drawing. This suggests that a large amount of practice alone is not sufficient for developing expertise, unless it is associated with a flexible approach to technique usage. This conclusion is further supported by the association between *lower* levels of actual drawing ability and higher levels of practice in surface learners. The uptake of strategies for practice has been shown to be a mediating factor in musical skill, with greater strategy use related to expertise development, rather than cumulative time spent practicing (Hallam, 2001), and in chess, in which practice strategies that extend beyond the repetitive and feedback-driven activities that typically feature in deliberate practice aid development of expertise (Campitelli & Gobet, 2011). Participants' perceptions of their own drawing skill were associated with a wide range of factors. They were more likely to say that they have relatively higher actual drawing ability if they are male, if they are less neurotic, if they are less open to experience, if they have more vivid mental images, if they practice more, and if they use more drawing techniques. Their level of practice and technique usage thus appears to artificially inflate students' perceptions of their *actual* drawing ability. In part this false inflation of the role of practice may be due to the popularisation of the expertise theory of 10,000 hours of deliberate practice (Ericsson, Krampe, & Tesch-Romer, 1993) which has been called into question in recent years (Hambrick et al., 2013). The degree to which students can effectively assess their ability and the contributions to it is a key aspect to focus upon in the context of art and design education.

Research suggests that the motivations and methods of different learning styles are as important in predicting outcomes in higher and further education as are measures such as general cognitive ability (Credé & Kuncel, 2008). Our analyses of background variables in figure 3 show that learning styles also have separable influences on a skill which is much less academic in its nature and which does not seem to relate to academic ability or general cognitive ability. Indeed, drawing ability appears to be causally independent of both educational attainment and individual differences in NVIQ, and we omitted them, for simplicity, from our path diagrams. Approaches to studying, however have a marked influence on strategies for drawing and subsequent outcomes in drawing ability. Surface learners spend more time drawing, but learn fewer techniques, and their actual drawing ability is less good. Deep learners do not show any actual drawing ability advantage. Finally,

achieving (strategic) learners, have higher actual drawing ability, so that their motivation to succeed has indeed been successful.

It was predicted in the current study that there would be a correlation between the personality traits of conscientiousness and openness to experience and drawing ability. Actual drawing ability had no direct influences from sex, the Big Five or VVI measures in the current study. However that is not to say though that sex, the Big Five and VVI are unimportant. They are all predictive of aspects of learning styles, which do directly predict drawing time, techniques and actual ability. Conscientiousness and openness to experience negatively predicted surface approaches to learning, which in turn was negatively associated with actual drawing ability, contrary to the suggestion that these personality characteristics would be positively associated with other approaches to studying, but in line with the proposal that they are related to drawing proficiency in some way. Both agreeableness and extroversion positively predicted achieving approaches to learning, which directly impacted on actual drawing ability, suggesting a strategy for success in representational drawing is a willingness to adhere to the task demands given and a desire to provide an approved outcome by the task instructor.

The present study confirms that performance on the copying and recall conditions of the ROCF are each independent predictors of actual drawing ability (figure 3) after taking the other into account, supporting findings from an earlier study (McManus et al., 2010). In the ROCF copying task, the figure itself is in full view throughout the task, which suggests that visual perception and attention may be poorer in those who draw less well. The ROCF delay task is to a large part a measure of long-term visual memory, the figure previously having been copied half an hour previously. It is not surprising that poor performance on the copy task results in poorer performance on the delayed task, but the independent effect of performance on the recall task on actual drawing ability suggests that long-term visual memory is also important in actual drawing ability. The use of drawing techniques appear to aid long-term memory, perhaps by giving students strategies for encoding visual information effectively. The relationship between perception, memory and drawing is one that has much support from the empirical literature (Cohen & Bennett, 1997; Glazek, 2012; Kozbelt, 2001; McManus et al., 2010) and is clearly a fruitful avenue of future research in its own right.

In summary, the development of proficiency in observational drawing is underpinned by individual differences in learning styles, which are themselves driven by differences in personality, particularly, conscientiousness and openness to experience. Learning styles differentially support engagement in drawing practice and strategies for drawing skill development which go on to affect drawing performance. While it describes the development of drawing ability, the structure of this model could be applied to a range of domains, in which the contributions of practice, aptitude and use of techniques or tools for learning can be isolated and measured. For example, in the field of music, the impact of personality, approaches to studying, time spent practicing and use of techniques

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for understanding musical notation on musical ability could be measured to test the applicability of the model. This research can help students in arts education to adopt study approaches that lead to the greatest gains in both understanding and performance. Specifically, more time spent practicing drawing on the basis of informed teaching that encourages an intelligent approach to seeing for drawing is likely to be a useful strategy, not only to those studying art and design, but to students with a wide range of educational goals.

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